MINING METHODS AND COSTS AT THE HIGHLAND SURPRISE MINE SHOSHONE COUNTY, IDAHO

BY D. W. BUTNER

* * * * * * * * * * **Information Circular 7560**

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1/ Mining engineer, U. S. Bureau of Mines.

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INTRODUCTION AND SUMMARY

This Information Circular, one of a series published by the Bureau of Mines, reports on the methods and costs of mining and concentrating zinc-lead ore at the Highland Surprise mine in the Pine Creek area of the Coeur d'Alene region of Idaho.

The mine is owned and operated by the Highland Surprise Consolidated Mining Co., which supervises operations of the Nevada Stewart group of claims, which is adjacent on the northwest. These properties are at the extreme eastern end of a zone of fracturing that strikes northwest across the Pine Creek area. In fractures along this zone are the principal Pine Creek mines; these are the Highland Surprise, Nevada Stewart, Sidney, Denver, V and Idaho, Liberal King, and Northern Light.

Country rock at the Highland Surprise is argillite of the Prichard formation (Belt series). Fracturing has permitted the movement of mineralizing agents that have replaced adjacent walls and crushed country rock with sulfides. Ore minerals are sphalerite and galena with accessory pyrite, chalcopyrite, pyrrhotite, and siderite. Three principal ore shoots were found on the Highland Surprise property. The Highland ore shoot was mined from outcrop to the 400 level. The Surprise ore body has been developed to a depth of 1,400 feet on the dip of the vein. The outcrop of the Surprise ore shoot was 150 feet long and 2 to 4 feet thick; on the 1,150 (lowest) level, the ore shoot is 320 feet long and 10 to 17 feet thick, with good zinc content. Surprise ore shoot No. 2 occurs 250 feet west of No. 1 and has been mined from the 500 to the 1,000 level.

From 353,000 tons of ore mined between 1910 and 1948, the property has a recorded production of 256,000 ounces of silver, 7,500 tons of lead, 24,000 tons of zinc, and 412 tons of copper.

Both shrinkage and cut and fill stoping methods are used at the Highland Surprise, but shrinkage is unsuitable for mining below the 700 level, because faulting has weakened the walls.

Development of the Surprise ore, as well as exploration laterally and along the strike, is prosecuted steadily. A prospect heading is being pushed westward toward Nevada Stewart ground from the 700 level.

The mill has a rated capacity of 275 tons per day and operates near capacity. Selective flotation makes zinc concentrate that is shipped to the Anaconda smelter and lead concentrate that is trucked to the Bunker Hill smelter at Kellogg.

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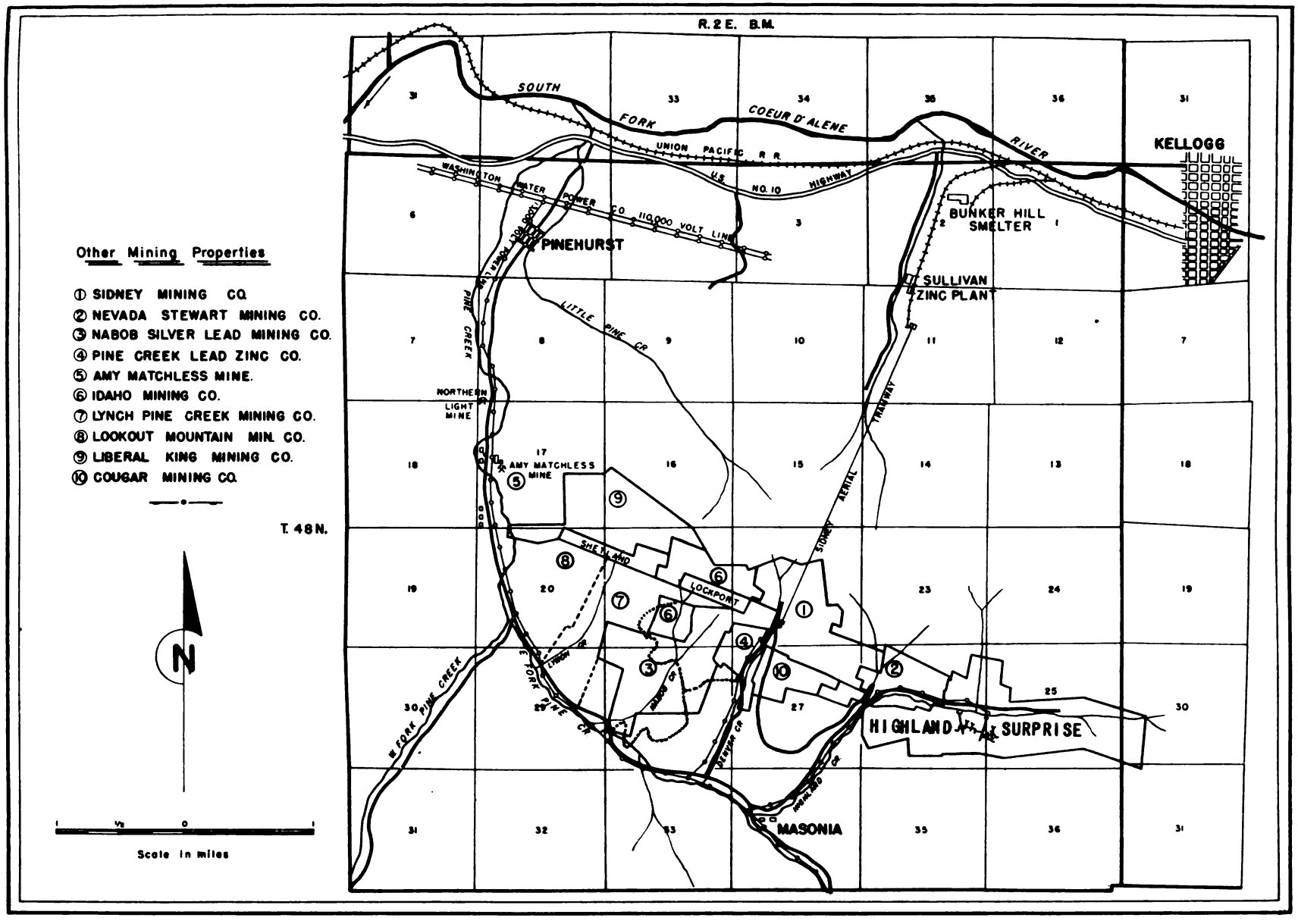

Figure 1. - Location map, part of Pine Creek district, Shoshone County, Idaho.

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Cost of the operation for the last quarter of 1948, mining and milling 21,671 tons, was:

	Per ton
Mining cost	$6.74
Milling cost	1.41
General expense	.75
	8.90

ACKNOWLEDGMENTS

The courteous cooperation of Frank H. Mitchell, general superintendent of the Highland Surprise Consolidated Mining Co., in obtaining the material for this report is gratefully acknowledged. Thanks are tendered, also, to the following members of the staff, who supplied needed information: C. L. Miller, engineer, Fillmore Murphy, mill foreman, and D. Baslington, mine foreman.

LOCATION AND ACCESSIBILITY

The Highland Surprise mine is situated in sections 25 and 26, T. 48 N., R. 2 E., Boise Meridian, on the headwaters of Highland Creek, a tributary of the East Fork of Pine Creek (see fig. 1). The property is 4 miles south of the main tunnel of the Bunker Hill and Sullivan mine, whose property adjoins the Highland Surprise claims on the north. Access is by U. S. Highway 10, going west from Kellogg, 5 miles to Pine Creek and following the Pine Creek road, taking the branch up the East Fork at the confluence of the East and South Forks, to Highland Creek, and turning up the Highland Creek road 2 miles to the mine, a total distance of 14 miles from Kellogg.

HISTORY

Mineral was discovered in the Pine Creek area in the 1880's soon after ore was found in the Coeur d'Alene district, but little mining was done until after 1910. The Highland Surprise claims were located about 1900; they produced ore to the value of $30,000 in 1912.2/ The property then was idle until 1914.

In 1916, Highland Surprise was Pine Creek's heaviest zinc producer; after that year operations were intermittent until 1941. Since then production has been more regular. The following statement of production covers the entire life of the mine:

2/ Umpleby, Joseph B., and Jones, E. L., Jr., Geology and Ore Deposits of Shoshone County, Idaho: U. S. Geol. Survey Bull. 732, 1923, p. 105.

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	Tons mined	Concentrate, tons	Silver, oz.	Lead, lb.	Zinc, lb.
1910-27 ..	110,310	-	120,355	5,360,000	14,560,000
1941	11,316	2,650	6,701	332,883	2,612,053
1942	17,808	2,171	7,739	541,531	2,036,626
1943	15,813	3,407	11,143	604,729	3,393,447
1944	34,857	5,436	18,665	1,200,481	5,103,061
1945	30,528	4,292	18,588	1,336,402	3,748,312
1946	25,940	3,503	19,760	1,434,436	2,750,611
1947	40,888	6,366	22,009	1,776,846	5,265,338
1948	65,461	10,034	31,527	2,606,951	8,511,987
Total ..	353,421	37,859	256,487	15,194,259	47,981,935

The additional recovery of 824,000 pounds of copper and 135.31 ounces of fine gold was recorded.

The presentowners took control of the company in 1943, and the present management at the mine was appointed in 1945. Since then, production has increased, ore reserves have been augmented, and development as well as exploration has been accelerated.

Highland Surprise now holds 52 claims, which cover a total area of about 900 acres.

The first mill on the property concentrated the ore by means of jigs and tables at the rate of about 50 tons per day. The second mill, built in 1925, made use of flotation to treat 120 tons per day and produced separate lead and zinc concentrates; the lead was hauled to the Bunker Hill smelter, and the zinc product was shipped to Belgium for reduction. In 1940-41, a new flotation mill with a capacity of 100 tons per day was constructed, which made a bulk concentrate of 50 percent zinc and 8 percent lead. After 1945, the mill was redesigned and reequipped to treat 275 tons of ore per day and produce separate concentrates of zinc and lead. Operation is steady at near the capacity of the plant.

PHYSICAL FEATURES AND CLIMATE

The steep slopes of the hillsides around the Highland Surprise support a growth of pine, fir, cedar, and tamarack that is dense on the north slopes. Highland Creek provides enough water for year-round operations. It drains the southwest slope of Kellogg Peak, which rises northeast of the mine to an altitude of 6,296 feet. Snowfall is not usually as heavy as in the winter of 1948-49, when 5 feet of snow was on the ground. The region has a pleasant summer climate.

LABOR AND LIVING CONDITIONS

A few key men and their families are given quarters at the mine; all other employees live along Pine Creek, in Smelterville, or in Kellogg and are transported to and from the mine by company bus. Good labor relations, good working conditions, and satisfactory earnings tend to keep employee turnover low, thus improving the morale and efficiency of the working force.

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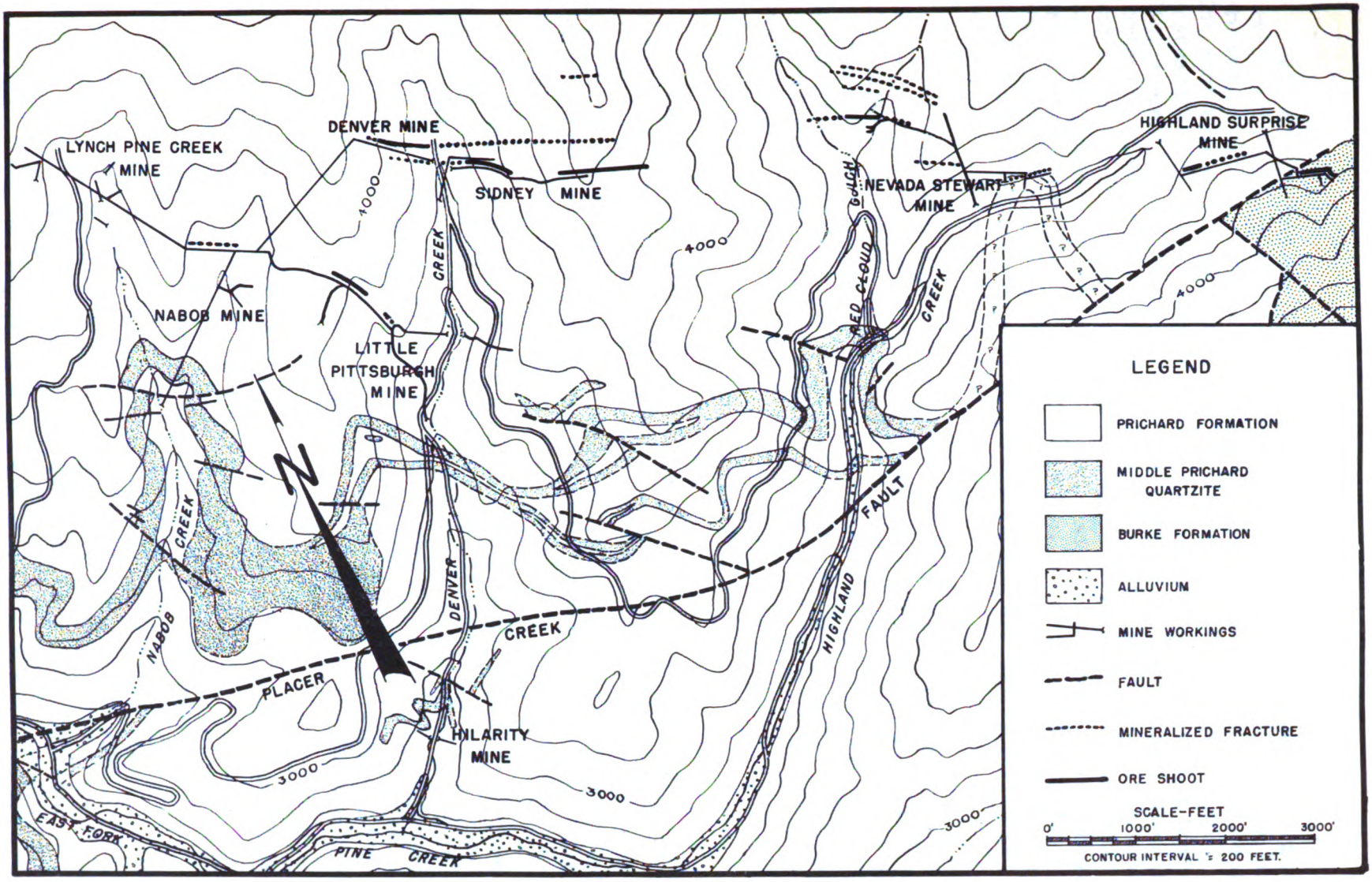

Figure 2. - Geologic map, east end Pine Creek district.
(Adapted from map by U.S.G.S.)

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GEOLOGY

All of the Pine Creek ore bodies have been deposited in the Prichard pre-Cambrian sedimentary rocks that cover the area (fig. 2). These beds are warped into a northwest-trending anticline, cut by much minor faulting. The most extensive faults are the Placer Creek fault, which strikes eastward across the area, a structure of great length and with a horizontal displacement on the order of 4,000 feet; the Pine Creek fault, an older northwest movement that is apparently cut off by the Placer Creek fault; and the north-south Government Gulch fault. This fault in Government Gulch is inferred by Jones 3/ to account for the juxtaposition of unrelated beds north of the Highland Surprise claims. The effect of this fault upon the mine's ore bodies has not been determined. The Prichard formation at Pine Creek comprises thin-bedded gray and black argillites with some interbedded light-colored quartzite.

The fracturing responsible for the deposition of the Pine Creek ore bodies strikes northwest and dips southwest. The ore fractures start from the Placer Creek fault at the Highland Surprise mine and are nearly continuous northwestward through the Nevada Stewart, Sidney, Denver, V and Idaho, Liberal King, and Northern Light mines. In the Highland Surprise deposit, mineralization was effected by some vein filling but principally by replacement of argillite in vein walls.

ORE DEPOSITS

Replacement of argillite by sphalerite and galena was virtually complete in the larger part of the ore shoots, though some fragments of unreplaced wall rock remain. The ends of the ore bodies show increasing amounts of quartz as the mineral deposit becomes leaner. Typically, the ore is a fine-grained mass of sphalerite and galena, with some pyrite and occasionally chalcopyrite. Pyrrhotite is present in many places.

Ore was mined from the Highland ore body before the Surprise ore shoots were developed. The Highland shaft was sunk on the vein from No. 4 adit to the 400 level. Stoped ore was hoisted up the shaft from the 100, 200, 300, and 400 levels and trammed out the adit. Subsequently, the Surprise 700 level was extended and connected with the deepened Highland shaft. Exploration from the shaft between the Highland 400 and Surprise 700 levels did not find ore. No ore is left in the Highland stopes.

The Surprise No. 1 ore shoot, now the principal source of production, increased in size downward, thus:

Surface	100 feet long	2 feet wide
300 level	150 feet long	3 feet wide
500 level	175 feet long	4 feet wide
700 level	180 feet long	8 feet wide
800 level	180 feet long	10.5 feet wide
900 level	200 feet long	14.2 feet wide
1,000 level	250 feet long	15-25 feet wide
1,150 level	320 feet long	10-17 feet wide

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The extra width of ore on the 1,000 level was the result of replacement of the wedge rock between two shear zones converging downward. The dip of the vein was 70° in the upper part, steepening to 82° on the 1,150 level.

A band of low-dip shearing cut through the ore shoot below the 700 level; this prevented continuation of mining by shrinkage stoping because of weakened walls. Cut and fill stopes were begun on the lower levels.

EXPLORATION

The rate of mining is paralleled by exploration. Underground, the walls of development and exploration openings are tested by diamond drilling; prospect drifts and crosscuts are driven through promising areas. The longest heading has been driven westward toward Nevada Stewart ground from the 700 level. In the spring of 1949 this search will be supplemented by a renewal of last year's bulldozer trenching and surface diamond drilling. A shear zone 45 to 100 feet wide and striking northwest from Highland Surprise through Nevada Stewart claims will be given more investigation.

Exploration headings are driven 5 by 7 feet on contract. Frequent turn-outs are used to switch cars. These turn-outs later are used for diamond-drill stations from which to investigate the walls for parallel structures.

DEVELOPMENT AND MINING

Development

The present development of the Surprise ore shoots is by an incline shaft in the hanging wall of the vein; it is 1,210 feet deep measured on the slope. The shaft has one compartment and a manway from the collar in No. 4 tunnel down to the 800 level. Below the 800 level the shaft contains two compartments and a manway. A hoist for the second compartment at the 800 level was used for sinking. Since sinking was finished, this hoist has been used to raise waste rock from development work to the 800 level for stope filling.

Levels driven from the shaft are designated in descending order: 200, 300, 500, 700, 800, 900, 1,000 and 1,150 (figs. 3 and 4). Present practice is to widen the drifts to the full width of the ore where they pass through the ore shoot. These wider sections of the drifts are heavily timbered; pony sets are placed above the drift sets. The pony sets are the same width as the drift sets, having 6-foot posts instead of 8-foot, as in the drift; all posts, caps, and sills are 12- by 12-inch timbers. Doubled 3-inch lagging is laid over the pony set caps.

Chute gates are installed when the drift is being timbered. Under blocks of ore that are to be mined by shrinkage stoping the chutes are 10 feet apart (fig. 5); under blocks of ore that will be mined by cut and fill stoping a 3-compartment timbered raise is started midway between the end raises of stope panels. Development raises are driven through the ore from level to level.

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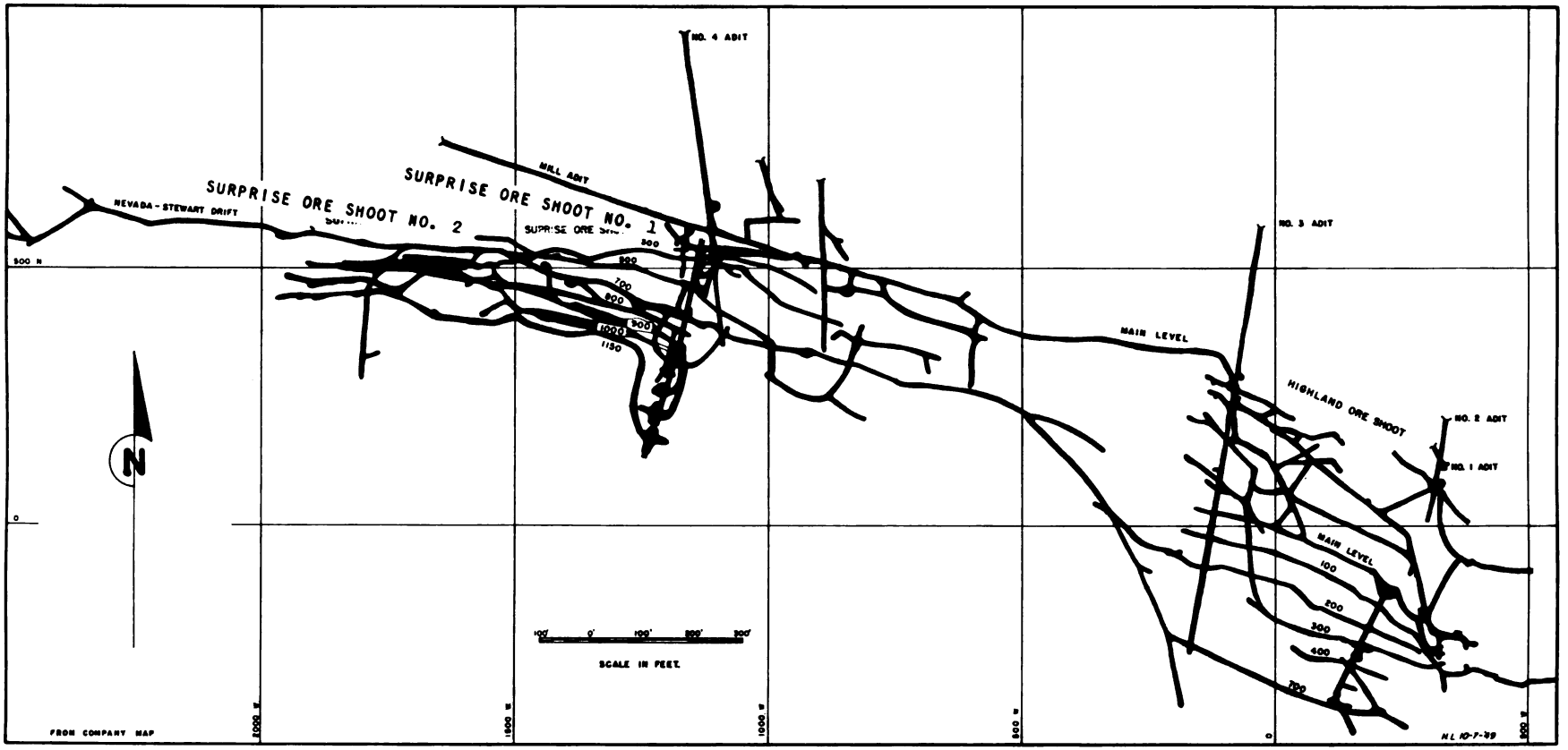

Figure 3. - Highland Surprise mine, underground workings.

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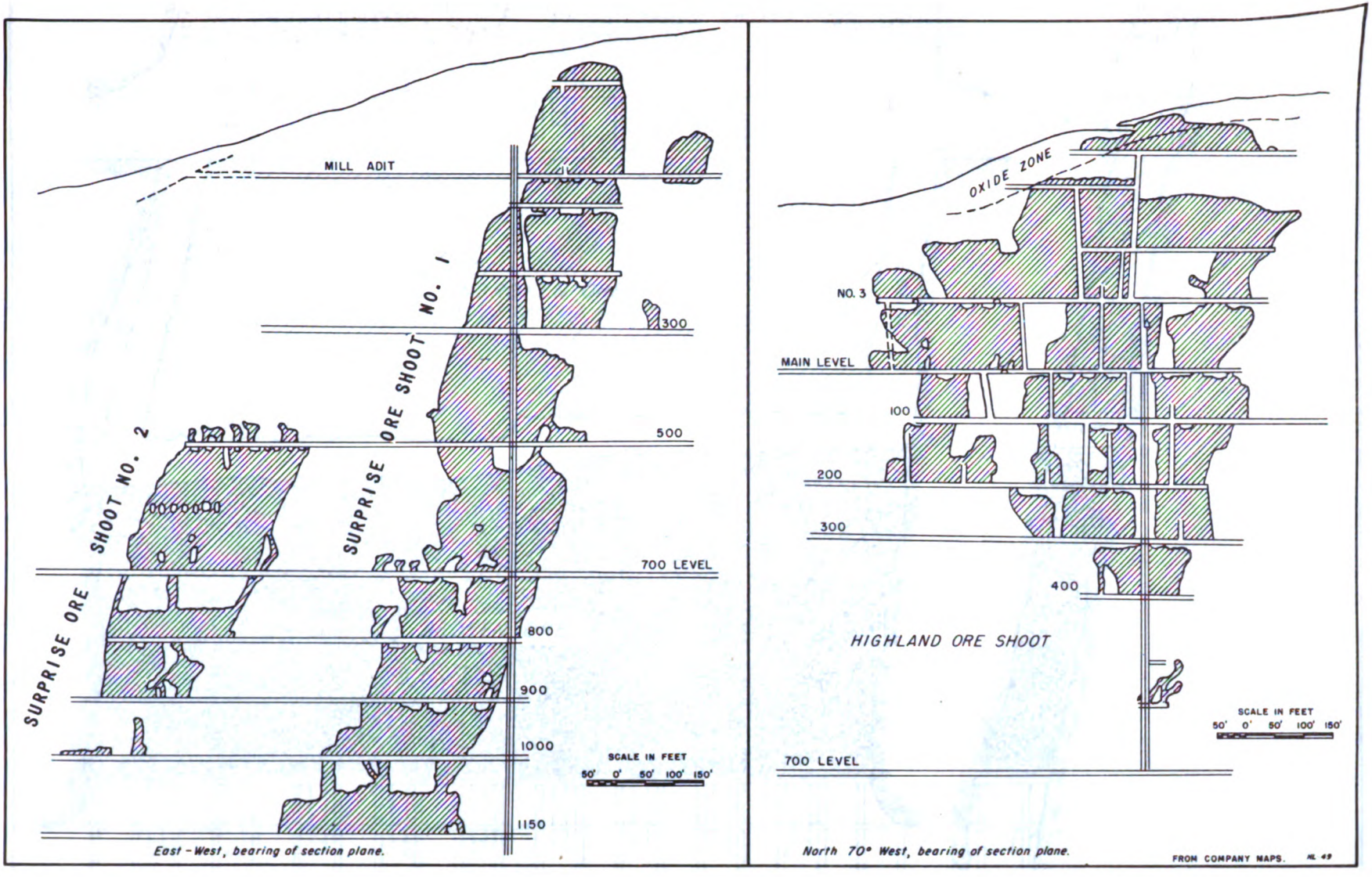

Figure 4. - Projected stope sections, Highland Surprise mine.

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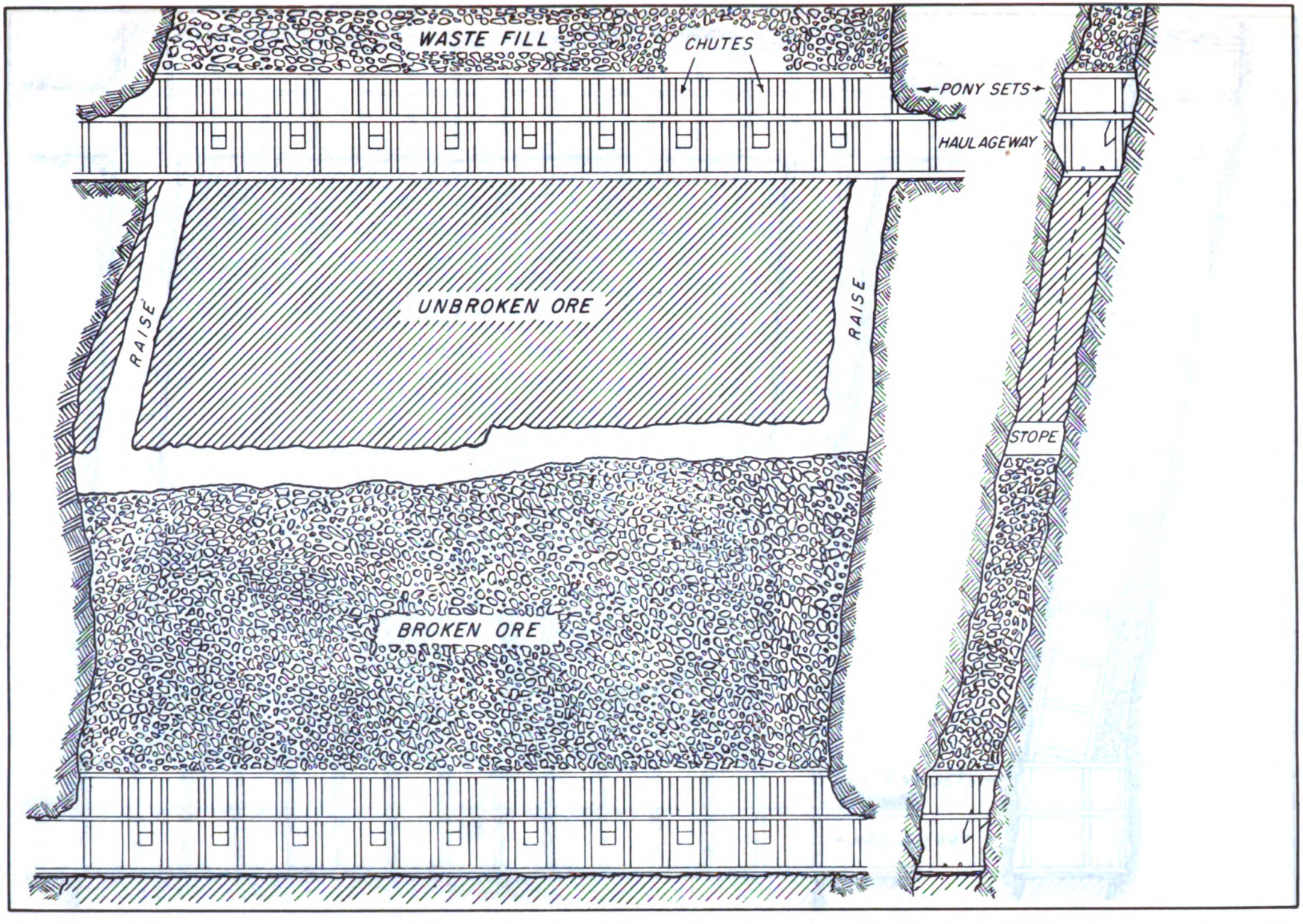

Figure 5. - Shrinkage stope, Highland Surprise mine, Pine Creek, Idaho.

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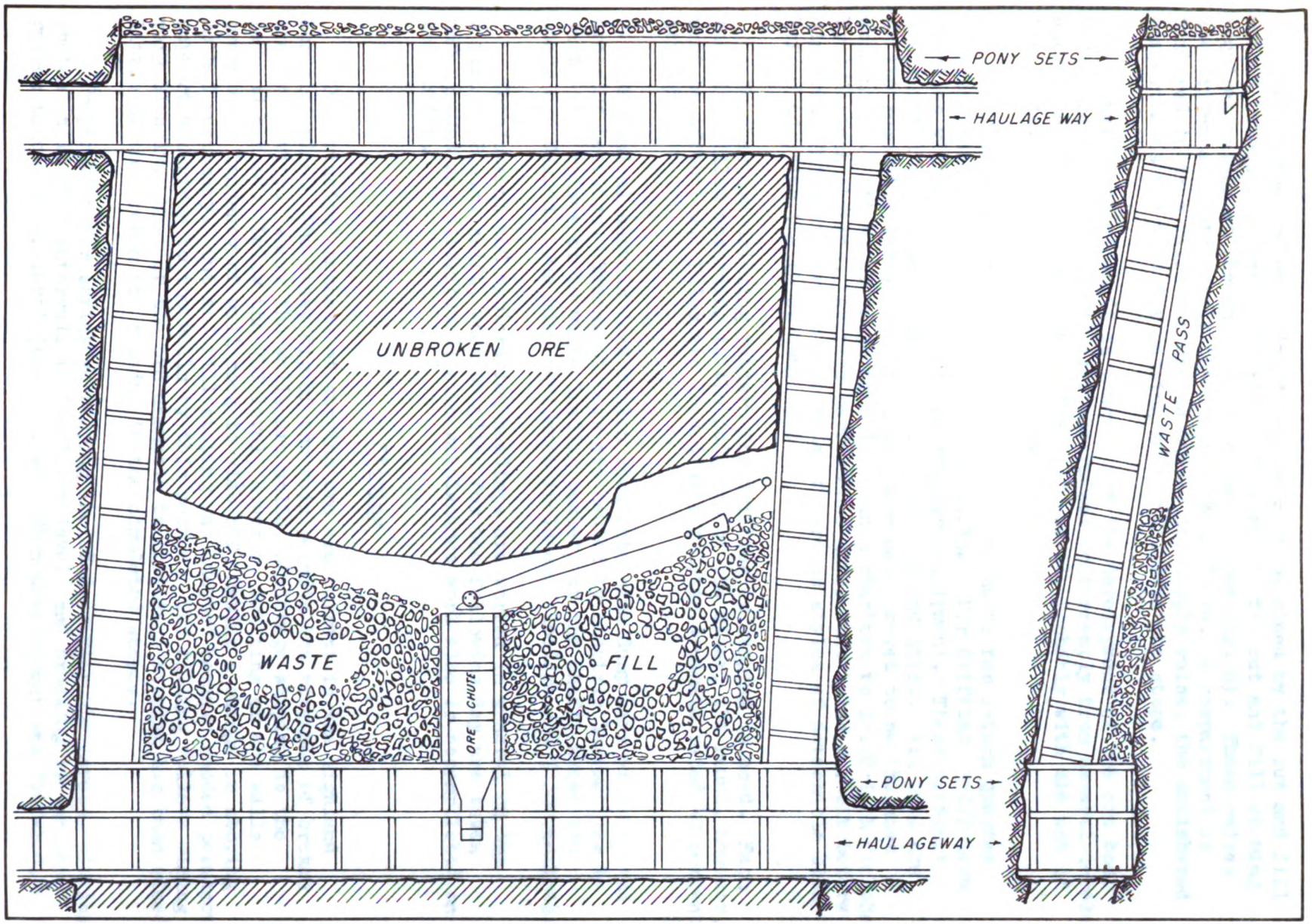

Figure 6. - Cut and fill stope, Highland Surprise mine.

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All of the ore now being developed must be mined by the cut and fill method because of fractured walls. Preparation for cut and fill stoping requires raises at the ends of stope panels (see fig. 6). These raises are driven as slots across the entire width of ore. A compartment is timbered in each raise for use as manway and supply raise; the untimbered compartments are used for passing waste fill into the stope.

A new vertical shaft is planned for the development of the ore body below the 1,150 level. It is to be raised concurrently from several levels above the 1,150 and sunk below the 1,150 level, probably with the use of the Riddell shaft-mucking apparatus.

Self-rotating stoper drills fitted with chucks for 1-inch quarter octagon steel are used in raising and stoping. For drifting, 3-1/2-inch machines with automatic mounts are standard equipment. These drifters are mounted on air bars; they use 1-1/4-inch round steel. All bits are of the removable throw-away type, as these have proved to be the most economical. Bit sizes range from 1-7/8-inch starters to 1-1/2-inch finishers by 1/16-inch changes. Average performance gives four holes per bit before discard. Extensive trails were made of various styles of detachable bits before adopting the throw-away type.

No standard drilling pattern for drifting or stoping is used. Each face is drilled according to the judgment of the miner; the round, however, must be effective. Holes are loaded with gelatin dynamite rated 40 percent strength.

Mechanical shovels load broken rock into side-dump cars at drift and crosscut headings. Trains of cars are hauled by electric locomotives to waste-fill raises or to waste loading pockets at the shaft, where the loads are dumped. The mine equipment includes 5 loaders and 7 locomotives.

Development and exploration headings are worked in general on the 6 p.m. to 2 a.m. shift, when supplies for the following day are taken underground and distributed; some maintenance work also is accomplished on this shift.

Stoping

Two principal methods of stoping ore are current in the Highland Surprise mine. The steep dip of the vein permits the movement of broken ore by gravity. Where the walls are solid, shrinkage stoping is the favored method. Below the 700 level, however, faulting of the walls promotes a tendency of wall rock to slab off, making a change in stoping method necessary. Cut and fill stoping was adopted because needed permanent support was given to the walls by this method. The filling follows mining very closely. Most of the ore amenable to shrinkage stoping has been mined; little of the broken ore remains in the completed stopes.

Preparation for shrinkage stoping included driving the levels, placing chutes at 10-foot intervals in the lower level, and breaking two or more raises to the upper level (see fig. 4). When development was finished, a

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flat back shrinkage stope was mined to the level above by the usual procedure, pillars being left where walls were weak or grade of ore was too low. No unusual difficulty was experienced in drawing ore from the chutes.

A typical cut and fill stope is illustrated in figure 5. When development is finished, a panel is defined by upper and lower levels and the end raises connecting them. The raises serve as manway and as waste passes. One raise is placed at the middle of the block in the lower level to serve as an ore pass. Stoping is started and slopes upward at a low angle from the central ore chute raise to the ends of the panel. A slusher is mounted at the ore pass, and a cycle of operations is established. The ore is drilled and blasted on both sides of the ore chute. The broken ore falls on lagging laid down before firing; the ore is scraped into the chute, and the lagging is removed; when needed, a set of timber is added to the 3-compartment raise; waste rock passed into the stope through the end raises is distributed by slushing; lagging is laid over the new fill, and the stope is ready to begin the next round. Generally, the cut and fill stope panels are not more than 90 feet long; in these panels the scraping is performed by air-operated slushers. Some panels, however, have been started with a length of 200 feet; in these stopes 15-horsepower hoists are used for slushing. Semi-box type scrapers 30 inches wide are found satisfactory.

Underground Transportation

All underground hauling is done by electric locomotives; 2 Atlas, 2 Mancha, and 2 Greenbergs are in service. Tracks are laid with 20-pound rails on 18-inch gage. Side-dump cars are loaded with stoped ore from standard timber chutes, hauled to the shaft, and dumped in shaft pockets. A 3-ton skip is loaded from the pockets and hoisted to the collar, where it dumps automatically into a bin. Another electric locomotive with a train of cars hauls ore from the shaft bin to the mill bin.

ORE RECOVERY

The total tonnage of minable-grade ore that is recovered by mining exceeds 95 percent. Much care is given to the selective breaking of ore near the boundaries of the deposit, but no regular manual sorting of waste from ore is practiced. In general, dilution in the shrinkage stopes is moderate, but broken walls sometimes introduce considerable waste.

At present, development supplies 20 percent of the mill feed; ore from cut and fill stopes amounts to 80 percent.

WAGE AND CONTRACT SYSTEMS

Most of the work at the mine is done by contract. The company benefits from the arrangement, and the employees prefer it. A wage scale is in use for work that cannot be contracted.

A natural circulation of air is induced by the difference in altitude of the collars of the two shafts, and this air flow is used to ventilate the mine workings.

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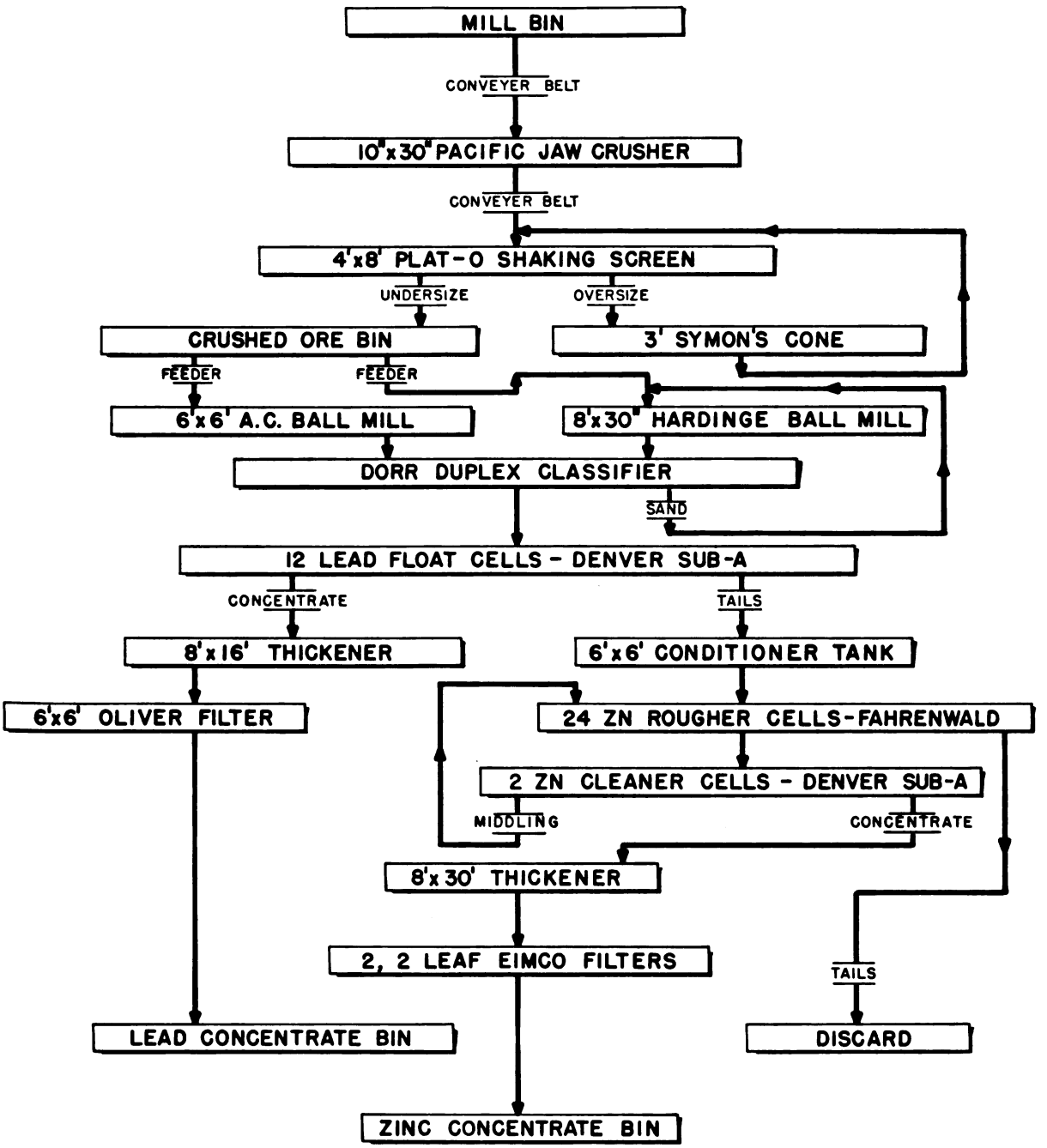

Figure 7. - Flow sheet of Highland Surprise mill, Pine Creek, Idaho.

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Company officials as well as representatives of the miners' union guard against unsafe conditions and practices in the mine. No regular safety-first classes are held. The record shows few accidents.

MILLING

The mill was redesigned after 1945, and its capacity was increased to 275 tons per day. The flow sheet is shown in figure 7. Ore is crushed and screened; screen oversize is reduced in a 3-foot cone, the product from which returns to the screen; screen undersize goes to a crushed-ore bin, from which two ball mills are fed. A duplex classifier receives the ground pulp, returning sand to the ball mill for regrinding and delivering conditioned pulp to lead flotation cells, the concentrate from which is thickened, filtered, and stored in a bin. Tailing from the lead flotation cells is conditioned in a tank and passed to a bank of zinc rougher cells, then to cleaner cells, from which a middling is returned to roughers; the concentrate is thickened, filtered, and dropped into a zinc-concentrate storage bin. Concentrates are shipped four times a week; the lead product is trucked to the Bunker Hill smelter near Kellogg, and the zinc concentrate to Wallace, from whence it is shipped by rail to the Anaconda smelter in Montana.

Milling is continuous for 6 days per week. An operator and a helper constitute the working force on each of three shifts; extra men work in the mill on day shift. Only repair work is done on Sunday.

Average assays of mill heads and tails for the last quarter of 1948 were as follow:

	Tons milled	Heads, percent		Tails, percent		Recovery, percent	
		Zinc	Lead	Zinc	Lead	Zinc	Lead
October	6,942	6.07	1.97	0.42	0.25	93.1	87.3
November	7,486	6.05	1.94	.54	.22	91.1	88.7
December	7,243	5.74	1.80	.65	.32	88.7	82.2
Total and average	21,671	5.95	1.90	.53	.26	90.9	86.1

From the ore milled, the following products were made:

	Zinc concentrates			Lead concentrates		
		Percent			Percent	
	Tons	Zinc	Lead	Tons	Lead	Zinc
October	763.37	51.70	1.65	206.26	56.24	15.50
November	858.71	48.13	1.86	199.25	57.48	14.26
December	700.27	49.80	1.75	179.24	55.12	15.00
Total and average	2,322.35	49.81	1.76	584.75	56.32	14.91

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Small concentrator tables at several points in the mill permit visual inspection of results at various stages.

Water for milling is drawn by gravity from Highland Creek the year round.

Like many of the concentrators in the Coeur d'Alene district, the mill is so situated in a narrow canyon that the area available for settling the mill tails in insufficient. An association of producing companies of the district has established a system of tailings removal on the Coeur d'Alene River near Cataldo Mission; this system operates for the benefit of all mills in the area drained by the river.

COSTS

Contract prices for underground work:

Exploration drift headings 5 x 7 feet, depending on distance from shaft ...	$6 to $8 per foot
Overbreak, in ore only	$0.10 per cubic foot
Breaking down back	$0.12 per cubic foot
Exploration raise 5 x 5 feet untimbered	$6 per foot
Development raise, variable in size ..	$0.125 per cubic foot
Shrinkage stoping	$0.06 per cubic foot
Cut and fill stoping	$0.10 per cubic foot

Wage rates for surface workmen:

Mechanics	$11.90 and $12.40
Electrician	11.90 and 12.40
Mill operator	11.90
Mill helper	11.40
Sawmill operator	12.40
Laborer	10.90

Prices of some supply items are as follows:

No. 4 Atlas dynamite	$16.85 per 100 lbs. at mine.
Fuse	10.30 per 1,000 feet
Caps	17.10 per 1,000
Electric delays	21.10 per 1,000
Timber 1/	35.00 to 40.00 per 1,000 board feet
Power	0.0065 per kilowatt hour

1/ Timber is logged by the company from its claims and is sawed in its own sawmill. Electric power is supplied by the Washington Water Power Co. at the mine at 2,300 volts, with little interruption of service. The cost, amounting to about $2,600 per month, is divided evenly between mining and milling. Power cost at the mine is distributed among the items in cost of mining.

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Shifts worked in the last quarter of 1948:

	Oct.	Nov.	Dec.	Total	Average month
Shift bosses	90	55	52	107	65.67
Ore breaking and transportation	700	646	618	1,964	654.67
Development and exploration	475	476	421	1,372	457.33
Other underground	219	420	505	1,144	381.33
Mechanical and surface	503	503	432	1,445	481.67
Total	1,987	2,100	2,035	6,122	2,040.67

Production in tons broken per man shift:

Ore breaking	6.11	6.69	6.72	6.51
Development	5.61	6.65	7.33	6.53
All mine employees	3.49	3.56	3.56	3.54

Direct mining and milling costs per ton, in the last quarter of 1948:

Mining cost per ton for the last quarter of 1948 was:

	Labor	Explosives	Comp. air bits, steel	Timber	Misc.	Total
Stoping, combination of shrinkage, cut-and-fill	$1.43	$0.29	$0.27	$0.38	$0.03	$2.40
Raising in ore	1.90	0.32	0.41	0.58	0.07	3.28
Drifting in ore	2.41	0.68	0.41	0.02	0.20	3.72

	Per ton
Cost of underground transportation	$0.20
Hoisting	.20
Surface transportation	.09

Mining:

Stoping	$1.44		
Raising in ore	.66		
Drifting in ore	.80		
Transportation and hoisting	.49		
Total stoping and development		$3.39	
Exploration		2.30	
Surface		1.05	
Total mining cost per ton			$6.74

Milling:

Labor	$0.48		
Supplies	.75		
Power	.18		
Total milling cost			$1.41
General expense			.75
Total direct mining and milling cost per ton			8.90

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